MARCH · 1941

TEN

THE TECH ENGINEERING NEWS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

MEETING A THREE-WAY DEMAND

A large fruit juice extractor looks so simple that there would not appear to be any special problems in the selection of materials for its parts. Yet, the screw must stand high pressures, and tramp iron can cause serious trouble. Ripe fruit won't wait for machine repairs.

Because it meets all three demands of the service so well one manufacturer of extractors now uses nothing but cast Carbon-Molybdenum steel for the screws. The steel (1) develops the requisite strength and toughness when normalized; (2) is comparatively inexpensive and (3) permits easy reconditioning when it is finally required — the worn spots being built up by welding and re-machined to original dimensions.

Here, then, is another case where the use of modern materials has economically achieved a distinct product benefit. Our book, "Molybdenum in Steel", is sent free on request to technical students and all others interested in modern materials for modern needs.

PRODUCERS OF MOLYBDENUM BRIQUETTES, FERRO-MOLYBDENUM, AND CALCIUM MOLYBDATE

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MOLY

THE TECH ENGINEERING NEWS

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OUR COVER THIS MONTH
Steel reaches the ingot stage
Photo courtesy
Jones & Laughlin Steel Corporation

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WIE STARK IST DIE KRAFT?

THE CINEMA INTEGRAPH USHERS IN A NEW ERA OF MATHEMATICAL EXACTNESS

By WILLIAM HEYSER '44

THIS question has been asked in every language of the civilized world. "*Quel en est l'effort?*" "*Hvor stort er presset?*" Or in English, "What is the Stress?"

The stresses of shearing and bending of a ship in a tumultuous sea involve many intricate factors. The righting moments of the hull in still water must first be determined, then the rolling moments, the pitching moments, the buoyant forces, and finally the stresses! Given the means for rapidly calculating these factors, the step by step integration of the differential equations of motion of the hull becomes practical. From motion to stress then becomes a relatively simple problem.

Engineers in the past have often had to rely on too ideal assumptions or on empirical methods in the solution of marine problems. But now, a new method to deal with such problems has arisen in the form of the cinema integraph, operating in Technology. This mathematical genie works problems in a few hours that would require weeks for the best human calculators!

Over a period of ten years the machine has been developed to its present stage by Gordon S. Brown '31, Assistant Professor of Electrical Engineering at M. I. T., with the collaboration of Professor Harold L. Hazen '24, Head of the Department.

Before undertaking a technical explanation of the integraph, let us first review the history of its predecessors. Fifteen years ago, Professor Norbert Wiener, the Institute's foremost authority on abstruse mathematics, conceived the idea that radiation, whether visible or invisible, might be used to reduce the labor of integration. The first instrument employing this basic principle was constructed by Dr. King E. Gould '25 in 1928. In this, thermocouples were made to measure infra-red radiations in amounts proportional to the positive and negative contributions of the integral to be calculated.

In the next few years the first visible radiation integraph was devised in which photoelectric cells measured amounts of light rather than invisible heat waves proportional to the integral of the product of the two functions represented by curves. This great improvement over the old machine, demonstrating its possible practical application to engineering problems, was the work of Dr. Truman S. Gray '29, now Assistant Professor in the Electrical Engineering Department at Tech.

The present machine, as the third in the series, is like the second in that varying amounts of light are used proportional to the mathematical functions to be integrated. However, a motion picture technique is employed, thus the name, "cinema integraph." The only one of its kind in the world, it may be seen in the Electrical Engineering Department at M. I. T. in a small room to itself, standing against a background of panel-wall switches and dials.

Yet surprisingly enough, though variations in the thickness of the film of a .0001 of an inch will react as convulsions in the machine, and the puff of a cigarette is catastrophic to its optical system, the principle on which it operates is relatively simple.

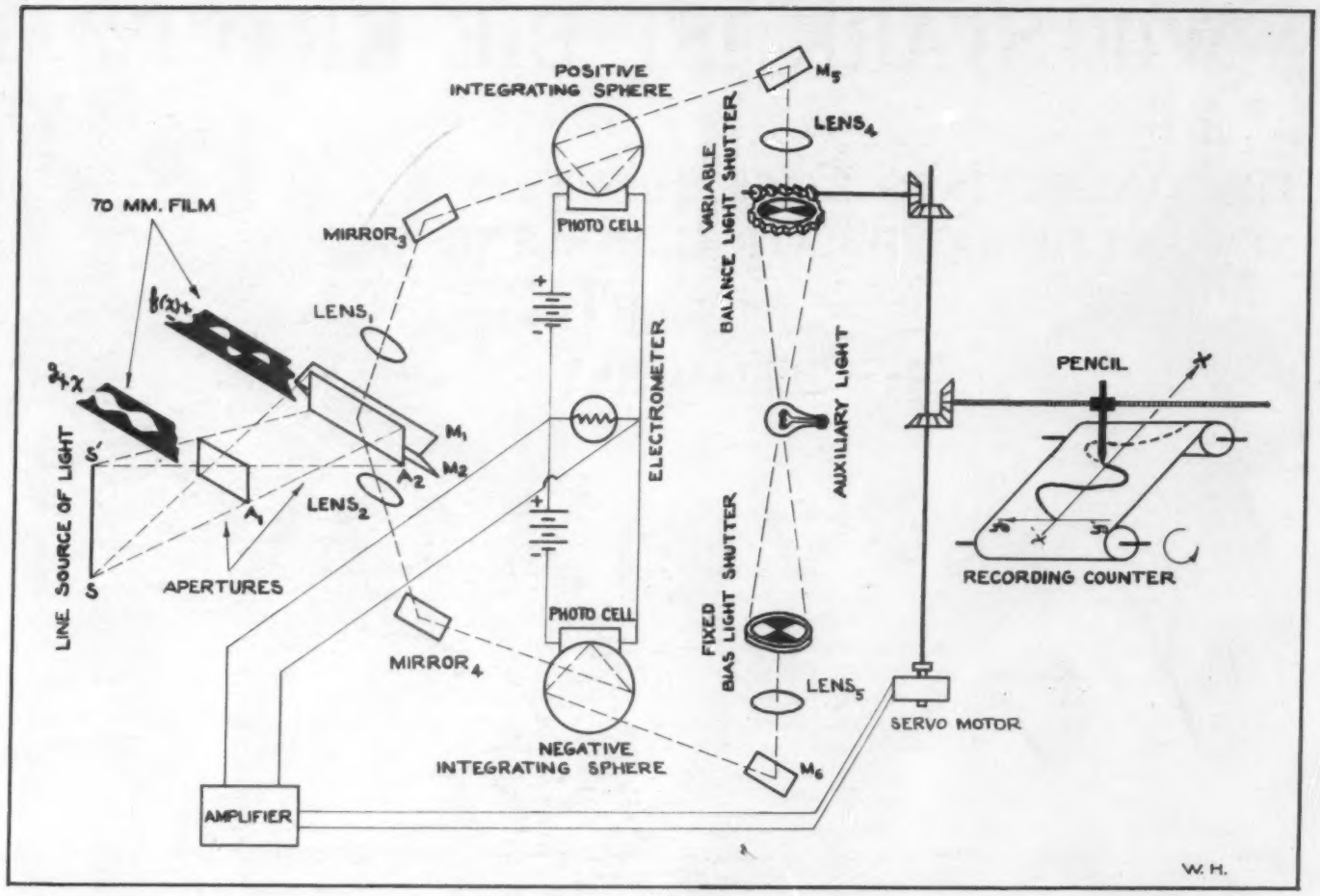
The entire system consists of a thin line source of light, apertures in which masked films are placed, an optical system of lenses, mirrors, "integrating spheres" with photocells attached, and finally a recording device. It is described formally by its makers as "a machine for evaluating a parametric product integral." In one of its more elementary forms, an equation of the type described may be expressed as:

$$F(y) = \int_a^b f(x, y)g(x)\,dx$$

where y is the variable parameter.

The explanation of how the multiplying and integrating in the above equation is accomplished will follow the simplified schematic diagram. SS' is the line source of light, a white hot tungsten filament in a vacuum tube, while A_1 and A_2 are apertures in which 70 mm. movie projector film is placed. Film must first be prepared by masking off the two functions to be multiplied and integrated, so that the area on each film for positive and negative values is the transparent part of the film. The preparation and transference to the film takes only a few minutes per function after the given variables have been plotted on a drafting board.

Now for the principle involved. Though by nature of the line source, A_2 is always bathed in light, it will be seen that the intensity of this light is contingent on the area of the film in A_1 which is transparent. For example, in a pinhole camera, the intensity of the light which enters is proportional to the size of the hole. If we consider a narrow strip of the film in the aperture A_2 of width dx, the intensity of the light passing through is proportional, in this case, to the ordinate of the curve. Likewise, the intensity of the light which leaves A_2 is proportional to the transparent area of the film in A_2. Therefore, if the film in A_1 represents the function $g+(x)$ and the film in A_2 corresponds to the function $f\pm(x)$, the total light flux leaving the aperture A_2 is proportional to the product of the two, expressed mathematically as:



A simplified schematic diagram of the integraph

$$\int_a^b g(x)\, f(x)\, dx.$$

Actually, two sets (only one set is shown) of apertures are used to deal with the two possible components of positive and negative values.

The two mirrors m_1 and m_2 directly behind A_2 are so placed that the positive light flux (passing above the X axis of the film) is reflected through the converging $lens_1$ and $mirror_3$ to the top integrating sphere. Similarly the negative flux enters the lower integrating sphere. The "integrating spheres" are merely hollow spheres, the interior of which is covered with magnesium oxide, a very efficient agent for diffusing the light before it is reflected into the attached photoelectric cells.

The two cells are connected together in series to form a photoelectric bridge with their batteries as two arms (the same circuit as a Wheatstone Bridge), a vacuum tube electrometer being in the measuring arm. The bridge is kept balanced at all times; that is, the current produced by the positive light flux must balance that produced by the negative flux. In order to maintain this equilibrium, it is necessary to introduce auxiliary light, *the amount of which is proportional to the ordinate of the solution*. The source of this auxiliary light is *constant*, and is supplied by the bulb indicated in the diagram. But, before entering the integrating spheres, through the lenses and mirrors, the amount of this light is varied to produce the required equilibrium of the bridge by means of the *fixed* "bias" shutter and the *variable* light shutter.

Automatic operation is achieved by connecting the electrometer to the input terminals of a d.c. vacuum tube amplifier, which in turn supplies direct current to the armature of a Servo motor. The motor is coupled by shafts and gears to both the variable shutter and the recording device, and may rotate in either direction. Consider, for example, that the upper integrating sphere has an excess of light. The motor is then actuated by the amplifier to turn in such a direction that the balance shutter allows less light to get by. At the same time the pencil on the recording shaft shuttles back and forth by means of a threaded attachment. The curve of the solution is drawn as the roll of recording paper unrolls along the X-axis as the film is moved in the aperture to correspond to new values of the variable parameter.

Like an index of business conditions, the stylus moves back and forth, recording the stability of a ship or a complex variable parameter! An important feature of the procedure is that analytic expressions for the functions are not required; the solution itself is a plotted curve, and likewise only plotted curves are required to handle the problem. The result can also be read on a pair of dials, printed automatically on paper tape, or obtained by all three devices simultaneously.

In the majority of problems an accuracy of within one per cent is obtained, sufficient for most engineering problems. The errors occurring in the solution are due to three sources: (1) the human element involved in the operations, (2) physical imperfections of the component parts, (3) limitations imposed by the design of the machine. The first source is usually negligible if the

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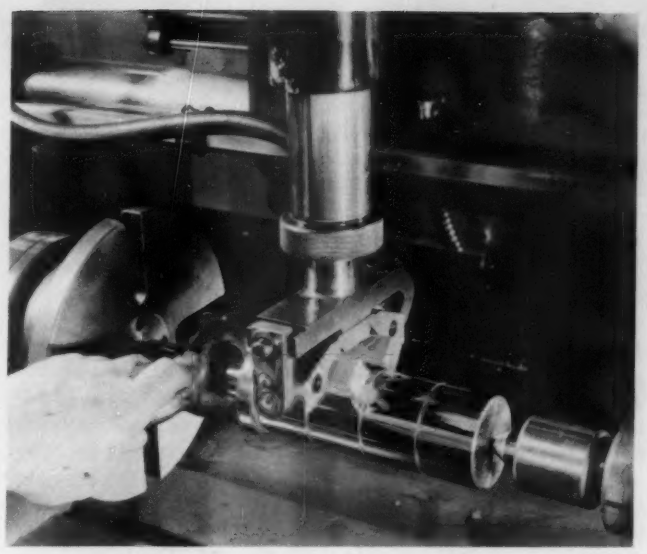


Chrysler

THE FIGHT AGAINST FRICTION

RESEARCH FINDS NEW WAYS TO COMBAT AN OLD ENEMY

By HARVEY FREEMAN '43

IF the sum total of all the power wasted in the United States through friction losses alone were to be computed, the figure would be staggering. Towards overcoming this loss, engineers and physicists have been working tirelessly in their fight against friction — technological advancement's inherent enemy. Since the day when the wheel was first conceived, man has realized the importance of a fine finish for the purpose of reducing friction, eliminating wear, and permitting quieter operation.

Before delving into this subject, perhaps it would be wise to investigate the nomenclature of surface finish. The terms "pitch" and "depth" mean the distance between the scratch peaks or "hills" and the depth of the scratches or "valleys." One must recognize the fact that, in many fine machining operations, the depth is small compared to the pitch and hence a microphotograph of the scratch would resemble a sagging rope. It is only after turning and rough grinding operations that the depth and pitch of any major irregularity are anywhere near the same.

Some machining operations use a fluid bath as a "coolant" and as a "lubricant." Its main function as a coolant is to keep the working surface cool, which is highly important in maintaining true crystalline structure. Its purpose as a lubricant is to wash away the tiny bits of metal that have been scrubbed off so that the abrasive will not be loaded.

"Abrasive pressure" is the amount of pressure exerted upon the abrasive material to produce the required surface. "Abrasive speed" is the speed of the abrasive stone or material needed to produce this surface. "Multimotion" is a term used to describe the varying speeds and directions which the abrasive assumes to attain geometrical trueness. "Crystalline metal" is metal in which the natural crystalline structure is undisturbed. The crystalline grains of solid metal are held together by a substantially amorphous metal cement which is destroyed as heat or pressure is applied.

If the quality of a surface is to be specified, some accurate means of registering surface defects must be employed. To achieve this end several devices have been developed. Beside the obvious methods of observation with the naked eye and scraping the fingernail across the surface, one may employ a profilometer, in which a tracer point is moved across the surface and the up and down movements are recorded on a graph. The point does not explore each valley as this would require an unreasonably long time to record the wanted information, but it does penetrate enough scratches to give an average reading of scratch depth. Several other means are available for obtaining these data. These methods deal with variations in light intensity or interference, and the utilization of X-rays and electron defraction.

In order to appreciate the importance of the superfinish process, it is well to understand other methods by which both dimension and finish are produced simultaneously. These processes are usually listed in the order of the quality of the finish they produce: turning, grinding, honing, sandpapering, burnishing, and lapping.

Turned finishes were first produced by the French lathes of 1570. Photomicrographs of a turned surface show it to be not cut or sliced, but wedged and torn. The friction developed by the chip sliding along the top of the tool results in tremendous heat. As all this heat cannot be carried away by the coolant and by the chip itself, much of it remains to decompose the surface material and produce a fragmented condition. The unit pressure on the point of a tool is amazingly high. Pressures as high as 200 tons per square inch have been observed on the turning points.

The history of turning falls naturally into four stages: the earliest period in which old carbon steels permitting a cutting speed of only 20 feet a minute were

used; the period around 1900 when high speed steels and new cutting methods increased the cutting speeds to 75 feet per minute; the time around 1915 when nonferrous alloys containing cobalt, chromium, and tungsten made speeds of 200 feet per minute possible, and the era after 1928 when tungsten carbined and tantalum carbides made their appearance and turning speeds of 500 feet per minute were realized.

Grinding was first developed merely as a means of changing dimensions and not of producing a smooth surface. The quality of a ground finish varies greatly depending upon the stone used; the difference, however, lies entirely in the magnitude of the scratch pitch.

The surface speed maintained in a grinding operation ranges from 6,000 to 8,000 feet per minute, and this speed, together with the necessary pressure, often produce temperature rises of 2,000 degrees. The fact that the melting point is often reached is evidenced by the white-hot condition of the sparks. The high temperature produced in this process results in an apparently smooth surface, but it has been proven that this surface is essentially smear metal.

The sandpaper finish was adopted by manufacturers as an improvement on the ground finish. This process makes use of a flexible abrasive paper, rather than an abrasive stone, for use particularly in camshaft work. It has been found, however, that this finish, although neat in appearance, is not very durable.

A burnished surface, although bright and shiny, is wavy and dimensionally inaccurate. For flat surfaces and outside cylindrical diameters, hardened steel rollers are forced, under tremendous pressure, to roll upon the surface. Inside diameters are often burnished by forcing hardened steel balls through their length. What actually happens is that the peaks or ridges of the burnished surface are bent over to cover up the valleys. Why this finish is unsatisfactory as a bearing surface is easily understood, for the surface is essentially porous and eventually will allow flaking.

Honing was developed for the internal machining of cylinder bores. This process emerged from a manufacturing need for greater speed and smoother surfaces. A number of bars of abrasive, usually four or five, are assembled in a holder circumferentially around the inside of the surface to be finished. These abrasive sticks, each of which is approximately half the length of the bore, rotate together and the entire assembly vibrates longitudinally. In this manner a cross-hatch scratch pattern is produced, instead of the line pattern associated with turned and ground surfaces. This is the first commercial method that utilizes a tool moving in more than one direction. Machining speeds for this operation are relatively low — 300 to 1,200 feet per minute.

Lapping is a hand method of removing small quantities of surface material by the use of a loose abrasive. This abrasive is similar to that used in solid wheel or bar grinding abrasives, but appears in the form of grit, and is usually mixed with oil or grease, thus being free to roll and produce a finish. This method, although it does produce a really fine finish, holds no commercial possibilities, as the skilled technician is the major factor in producing a good lapping job. Also the time required to produce a finish by this method would make the production cost prohibitive. Yet, because it is produced at slow speed, low pressure, and varying degrees of multimotion, lapping is one of the finest surface finishes known today.

With this background, one can more easily understand the Superfinish process of the Chrysler Corporation. The finishing tool used in this operation is a bar of bonded abrasive of relatively coarse grits. A fine stone is not needed in this process unless a surface with a scratch depth approaching two microinches is desired (a microinch is one millionth of an inch). For ordinary purposes a scratch depth of from 10 to 25 microinches is sufficient for finishing purposes.

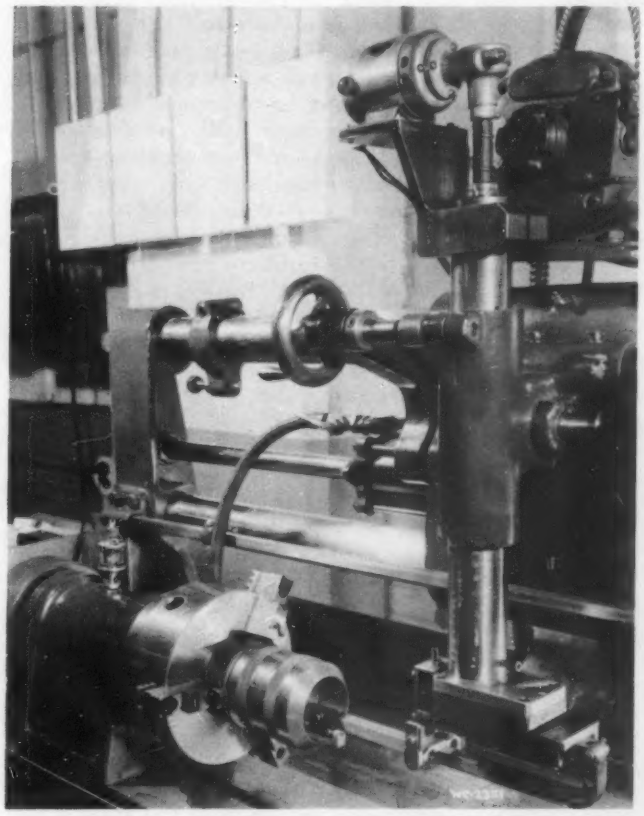
The multimotion of Superfinish is perhaps the chief characteristic of the entire operation. This series of motions can be realized through diverse methods of moving both the work and stone. This is exactly the case as exemplified by the Chrysler process, in which reciprocation is carried out by the abrasive block, oscillation by the stone holder, and an eccentric rotation by the work itself. In this manner, myriads of scratch patterns are produced, which fact is a dominant reason for the smoothness of the Chrysler finish.

It is evident that if, on a surface of "hills," one exerts a pressure, one does not apply an equal stress on all parts of the surface, but rather a concentration on the relatively small area of the tops of the "hills." Consequently, in the Superfinish process, a large abrasive pressure is applied, as an actually small force will represent a relatively large cutting force on the minute areas of actual contact. One may now infer correctly that it takes no longer to dress a rough surface than one which has a moderately fine finish already.

A fine commercial aspect of this finish is that Superfinish abrasive stones rarely, if ever, need dressing. At the end of the operation, the stone is glazed and loaded, but after the work is removed and the next part mounted in place, the oscillation of the stone across the sharp peaks of the rough surface causes it to dress itself in the first second of the operation. The abrasive speed is relatively slow, being 10 to 50 feet per minute.

(*Continued on page 46*)

Finishing an internal surface with a general purpose machine *Chrysler*



MAN VS. WEATHER

NEW GADGETS FOR THE WEATHER MAN

By

ALAN S. MICHAELS '44

THE Greeks had a name for it—they called it "meteorology." It had a much broader meaning to them, however, than it does to us in the present day. To the ancients, meteorology was accepted in its literal meaning: the "study of things above." It included everything from the rise and fall of the tides to the flashing of a comet across the sky.

Yet today, what an unwieldy science meteorology would be if it encompassed all these topics! It would include astronomy, heliography, spectroscopy, horology, and dozens of others. But fortunately the scope of that science has been confined to the study and analysis of the weather; and since the dawn of history this study has always been one of man's greatest concerns, and will become increasingly important with the passage of time.

It was not so very long ago that weather predictions were so inaccurate that farmers could do nothing but curse when their crops were killed by an early frost, or burned by a blistering sun. One need not go back very far to find instances where ships left port with supposedly good weather before them, were caught in severe storms, and never seen again. And in the early days of aviation many a pilot lost his life as a result of incorrect forecasts.

But now it is quite different. Recent advancements in weather analysis have produced startling improvements in accuracy, and especially in what we shall call "pre-determination" of weather changes. That is, reports that are found in the daily newspapers today are accurate to twenty-four hours from the time of publication.

That *is* something. Greek weather analysis was limited to such comparatively trivial things as measuring rainfall in an old clay jug, or finding the wind's direction with a wisp of grass. It was not until the beginning of the seventeenth century that things began to click. There came in rapid succession the thermometer, the barometer, the anemometer, the hygrometer, the maximum and minimum thermometer, the barograph, and the thermograph — yet no one could predict weather a day in advance; and there was a good reason for it, too.

No one knew what "weather" really was! True, it

Harold Orne

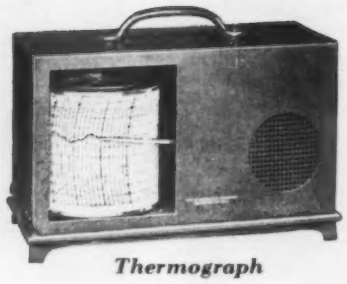
The new building of the Mt. Washington Observatory. In the foreground the wooden tower supporting the special electrically heated anemometer and the wind vane. In the background the Yankee Network FM radio tower.

was seen that changes in temperature, pressure, wind velocity, and humidity brought corresponding changes in the weather, but no one knew why. The whole trouble lay in the fact that *everyone saw weather in two dimensions* — length and breadth. This is quite understandable. It is difficult enough to believe that air has any dimensions, let alone three. But as soon as *height* was brought into the picture, things began to clear up. From this third-dimensional concept developed the famous and world-accepted "air-mass-front" system of weather analysis, introduced into this country by M. I. T.'s Professor Carl G. Rossby. The theory is essentially this: Disturbances are not found in one mass of air or in another; but rather at the junction of two such masses. When a warm body of air (usually of tropic origin) comes in contact with a cooler body of air (usually of polar origin), the cooler air forms a kind of wedge under the warmer, and a physical reaction takes place. Such a reaction may be the formation of rain, snow, fog, etc., depending upon the temperature and other factors.

Now that a suitable system of analyzing the weather had been perfected, there arose the need of rapid transmission of the forecasts. By far the greatest advancement in meteorological survey work was the invention of the radio and teletype. Today reports are sent (in code) from San Francisco to New York City in a minute's time. All storm centers and high pressure areas

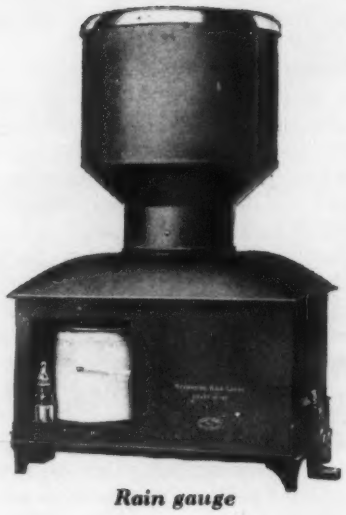
EARMARKING

Harold Orne



Thermograph

Operating the Nephoscope for the determination of direction and velocity of cloud movement. The motion of the cloud image is followed in a black mirror by means of a movable sighting eye-piece. The crystal ball on the cylindrical can is a sunshine recorder.



Rain gauge

Harold Orne

Shielded gauges to collect and measure the snow or rain on Mt. Washington. The purpose of the shield is to prevent the strong winds from producing a faulty catch. The average of several gauges is taken in order to assure more accuracy.

Pressure tube anemometer on top of Yankee Network Weather Observatory. This instrument records the wind direction and wind velocity as well as gustiness. Instrument shelter and rain gauge in right and left hand corners respectively.

Harold Orne

G

THE WEATHER

Sunshine recorder

Cup anemometer

Measuring the melted snow catch

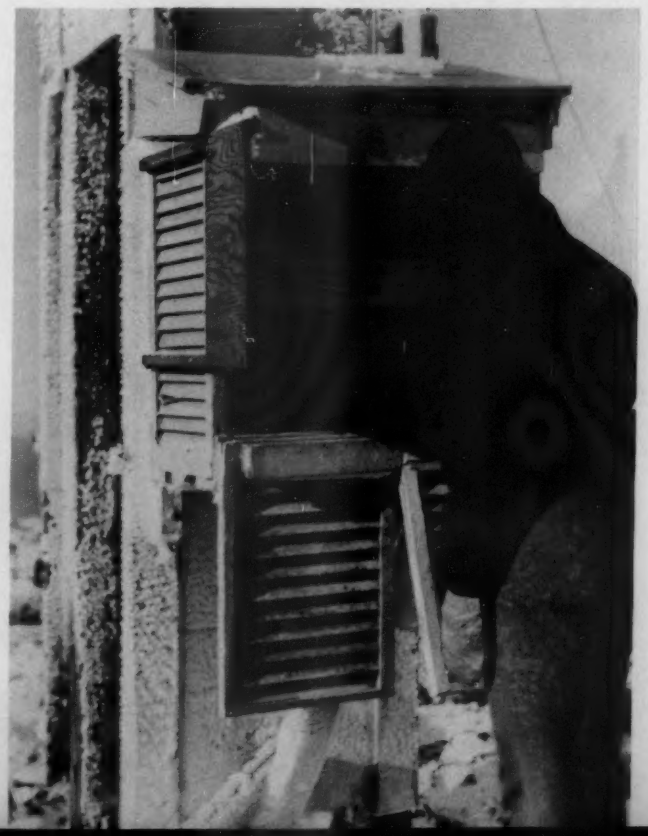
Harold Orne

Harold Orne

Recorder for the pressure tube anemometer and wind vane

Reading standard maximum and minimum thermometers on the summit of Mt. Washington

Harold Orne



travel from west to east (counter-clockwise) as is explained below.

The earth rotates west to east about its axis once in twenty-four hours, a body at the equator thus having a linear velocity of about seventeen miles per minute with respect to the center of the earth. At the North Pole a body has a linear velocity of zero miles per minute. Therefore, at any point above the equator and below the North Pole there is a stronger rotatory force on the *south* side of a body than on the *north* side. On fluids this force produces a counter-clockwise rotary motion called a *cyclone* in air masses, and a *whirlpool* in liquids. (The famous "Maelstrom" off the coast of Norway always rotates in a counter-clockwise direction.) The nearer to the equator, the stronger becomes the pull from west to east; thus the west-to-east and circular motion of the air. South of the equator the situation is half reversed; fluids rotate *clockwise*, but still west to east.

In this manner satisfactory predictions two and three days ahead of time can sometimes be made. Farmers can protect their crops, the great airlines can send up planes without fear of the old "unexpected storms." In fact, it has been recently said that due to late progress in meteorology, bad weather has "become an inconvenience, rather than a hazard" to air transportation.

Constantly new devices are turning up which increase the efficiency and speed of weather analysis. Perhaps one of the newest and most interesting is the *radiosonde.* If you can picture a combined observatory and broadcasting station weighing a little over a pound attached to a five-foot helium balloon, you have a pretty good idea of what one looks like. Weather men send these devices ten and twenty miles into the upper air, where radio reports are sent back of temperature, air pressure, and humidity at various intervals along the ascent. From these data it is possible to determine weather conditions at higher altitudes, and correlate those observations with future disturbances near the earth's surface.

An even more recent development is the automatic weather station that broadcasts observations of barometric pressure, air temperature, relative humidity, wind direction, wind velocity, and rainfall from some isolated point. Working on a principle similar to the radiosonde, it has become most useful for obtaining observations in heretofore inaccessible locations.

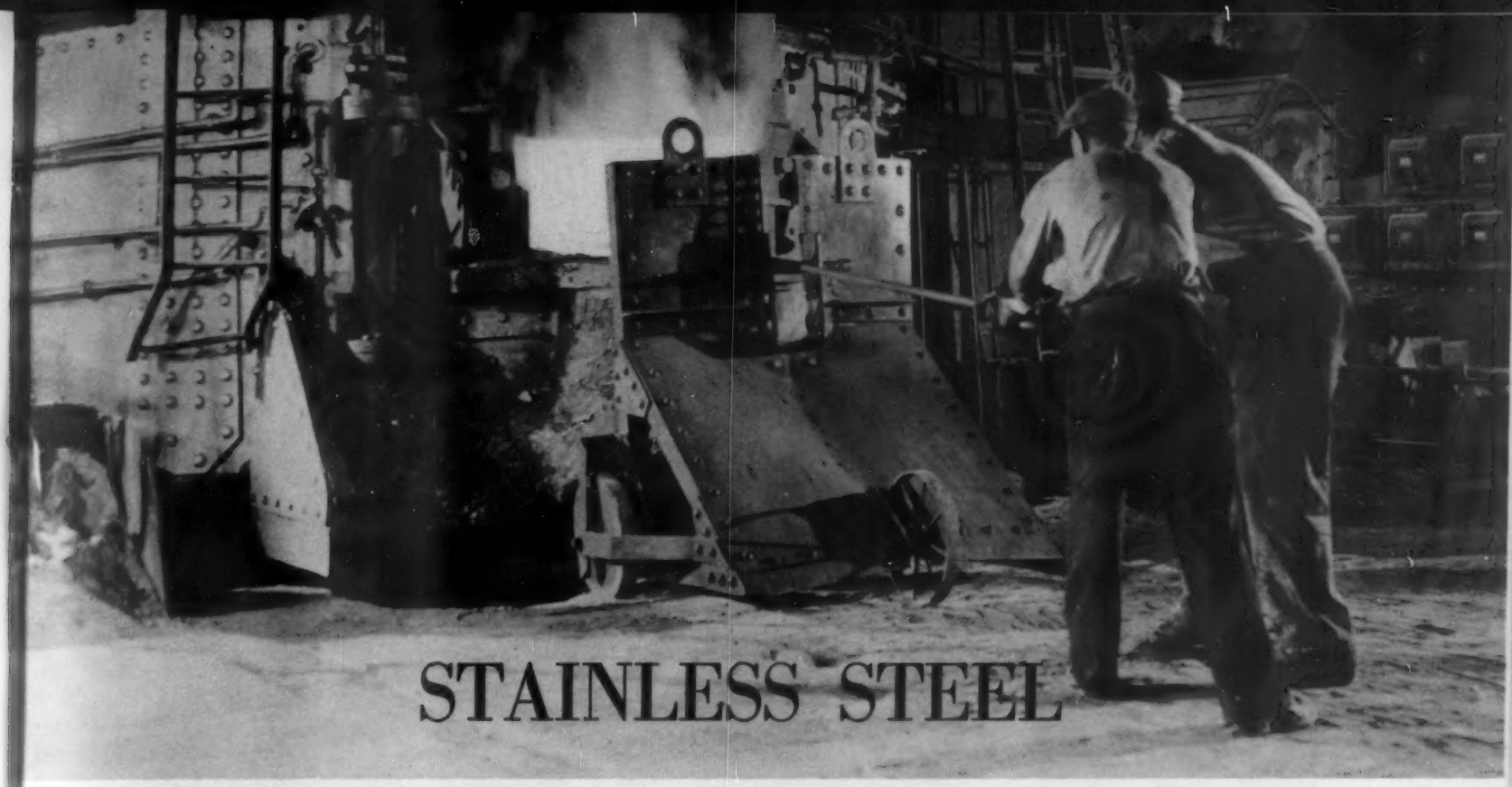
The final product of all these observations is the familiar weather map. Here all the collected data, not from one observatory, but from every point on the map, are put down and grouped together. From it weather men can tell where storm centers are, in what direction and how fast they are moving, what the temperature is in one part of the country as contrasted with another. The isobars and the isotherms divide the country or section into the different air masses which determine the direction and intensity of disturbances, and make it possible to "see" weather hours ahead of schedule.

What else can there be for us in the weather, now that we have proceeded so far in analyzing its actions? The answer: Plenty. There is still considerable doubt abo t the controlling factors of climate, pressure change, wind velocity, and many other important and interest-

(*Continued on page 44*)

Pilot balloon observation on Mt. Washington. These balloons are hydrogen inflated, and rise at a constant rate of ascent. By following their course with a theodolite, and reading the angle of elevation and the angle of direction at regular interrals, it is possible to determine the speed and direction of the upper air currents.

Harold Orne



STAINLESS STEEL

Carnegie-Illinois Steel Corporation

INDUCED PASSIVITY OPENS A NEW FIELD FOR STEEL ALLOYS

By STANLEY M. FELIX '44

ATMOSPHERIC conditions, chemicals, food acids, moisture, and myriads of other causes take their toll of corrosion and rust from steel every day. Scientific research has for years endeavored to find some permanent method of protection other than surface coatings which were, in themselves, liable to deterioration. Today there is still no single metal or known alloy that is absolutely invulnerable to all corrosion and attack under all conditions, or that comes closer to possession of these ideal properties than does stainless steel.

What is stainless steel? Stainless steel is that steel which has the property, when properly hardened and finished, of resistance against corrosion and oxidation by most media.

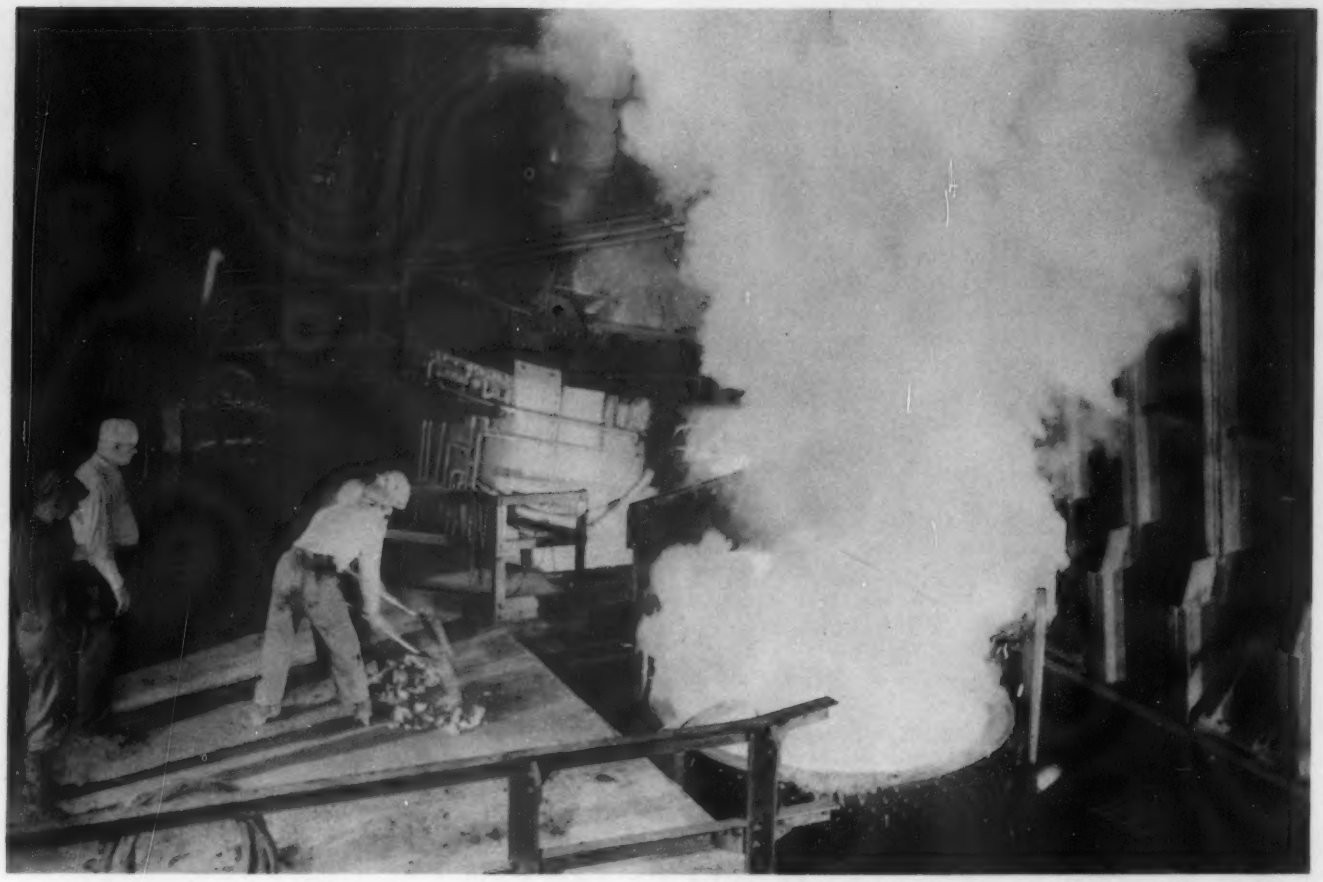
The first step in the development of stainless steel was taken by Faraday and Stoddard in 1820. They conceived the idea of adding chromium to steel. They thought that this new element might replace carbon in steel used for tools. This was proven false when it was shown that chromium without carbon produces no hardening effect on steel. The non-corrosive properties of steel mixed with chromium were first noticed by the Englishmen, Woods and Clarke, in 1872. The first to actually apply the useful properties of the alloys to everyday use were the American, Elwood Haynes, and the Englishman, Harry Brearly, in 1913. Undoubtedly the credit should go to Brearly, since it was his type of stainless steel that first was produced commercially.

In the manufacture of stainless steel, the various constituents are melted in either an electric furnace or crucible. Chromium ore and a reducing agent are added directly to a tank of molten steel along with suitable fluxes. The reducing agents, such as silicon or carbon, are oxidized, and the chromium reduced from the ore during this reaction enters the steel. In this way no carbon is introduced into the steel with the chromium and the chromium is homogeneously spread throughout the steel, since the reduction reaction took place over the entire surface of the molten steel. It is then cast in the form of ingots, which are annealed at 1380° F. (748° C.) for thirteen hours. They are finally cooled slowly down to atmospheric temperature, which makes machining simpler.

Before working, the ingots are soaked for some time at 1290° F. (697° C.) to insure softness. The ingots are then heated to 1650° F. (898° C.) and worked. If, after working, the steel is allowed to cool freely in the air, it will harden. The hardness depends upon the temperature of working and may vary from a Brinell hardness of 250 to one of 500.

The essential element of stainless steel alloys is chromium. The greater the amount of chromium, the higher the resistance to oxidation at high temperatures and the better the resistance against corrosion. These increased resistances progress with but are not proportional to the increase of chrome content. The effect of the chromium is to form, upon contact with oxygen, a thin, transparent, and unbreakable film which prevents further oxidation. This condition is practically ideal, for, if the film breaks, it will re-form.

Stainless steel is known as a "high alloy steel," which denotes an alloy content that is greater than 10 per cent. This class includes the corrosion-resisting



Tapping an electric furnace heat *Carnegie-Illinois Steel Corporation*

steels, any one of which must contain at least twelve per cent chromium. The element, chromium, may be present in the amount of 30 per cent, or even more. Chromium's effect on corrosion-resistance is modified by the addition of other elements. Nickel, molybdenum, titanium, and others all have their effect on the steel alloys.

"Chromium in correct proportions induces passivity in steels under oxidizing conditions. Many worth-while alloys have been developed on this foundation. Nickel, on the other hand, is peculiarly resistant to attack under reducing conditions. Therefore, it is only natural to suppose that combinations of the two alloying elements in proper proportions would produce steel with greater resistance to many kinds of corrosion that could be secured from either one alone. Steels of the chromium-nickel type are therefore resistant to a much greater variety of chemical attack than the plain chromium steels. No one class of steel resists all types of corrosion or possesses mechanical properties that would fit it for every application. Today engineers in all fields, and especially chemical engineers, much concern themselves with the modern corrosion-resistant steels now available in a great variety of compositions and mechanical properties."[1]

We can easily divide the stainless steels into three main groups: the chrome-nickel alloys that are non-magnetic and which cannot be hardened by heat treatment; the straight magnetic chrome alloys that are hardenable by heat treatment; and the straight magnetic chromium alloys that do not harden in the heat treatment.

The first commercially acceptable stainless steels contained 12 to 14 per cent chromium and were used simply for cutlery. The better cutlery steel now contains about 16 or 17 per cent chromium. The amount of carbon present in such grades of the alloys is almost twice as much as in the original steels. Articles made from these steels are so common today that they are sold from the counters of dime stores. It is often hard to realize that stainless steel is of such recent advent. Many articles and tools such as valve parts, scrapers, and dies, requiring a good combination of hardness with corrosion and wear resistance, are made from this group of steels. By making very slight changes in composition and heat treatment, wide ranges of mechanical properties are obtainable. Thus, the engineer has available today steels that combine extraordinary strength with resistance against corrosion. It cannot surprise anyone that such materials were rapidly adopted for use in industry.

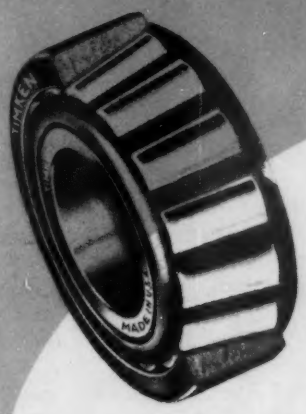
Lowering of the carbon content and an increase in the chrome content enhance the workability and corrosion-resistance of stainless steel. It cannot be varied by change of heat treatment when it contains as much as 16 to 18 per cent chromium and only 0.15 per cent carbon, but it still has wide industrial use.

"Steels of still higher chromium content have contributed their share to progress. Even prior to commercialization of stainless steels of the low carbon type, steels having chromium contents from 20 to 30 per cent had made appreciable industrial headway, particularly in the form of castings. Great resistance to oxidation at high temperatures and excellent resistance to wear gave the steels containing more than 20 per cent chromium their early start. Also, it was soon found that they are especially valuable where resistance to

(*Continued on page 43*)

[1] J. H. Critchett: "Twenty Years of Alloy Steel," *Chemical Industries Magazine*, March and April, 1940.

EVERY GOOD ENGINEER MUST KNOW HIS BEARINGS



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FRANKLY SPEAKING...

"THROUGH A GLASS, DARKLY"

— I Corinthians 13: 12

Behind the present scenes of industrial preparedness lurks a significant, little-thought-of question: "After the war, what then?" At the annual dinner of the American Society of Mechanical Engineers, Mr. W. L. Batt, past president, gave an address well worth serious, objective reading. He attempted to show how we must cope with the question concerning the future — a future in a world tremendously changed from the one we now know.

Mr. Batt asserted he believed that today in England capitalistic imperialism and individual control of great financial and economic power were as dead as the feudal system. He pointed out that it is the wage earners and middle classes who shout "This war will bloody well be fought to a finish." He quoted Ernest Bevin as saying that this war must be followed by "economic reconstruction of the whole foundation of society. . . . The task of rebuilding the world has to be done by the working class." It is significant that two of the seven British cabinet members represent the Labor Party.

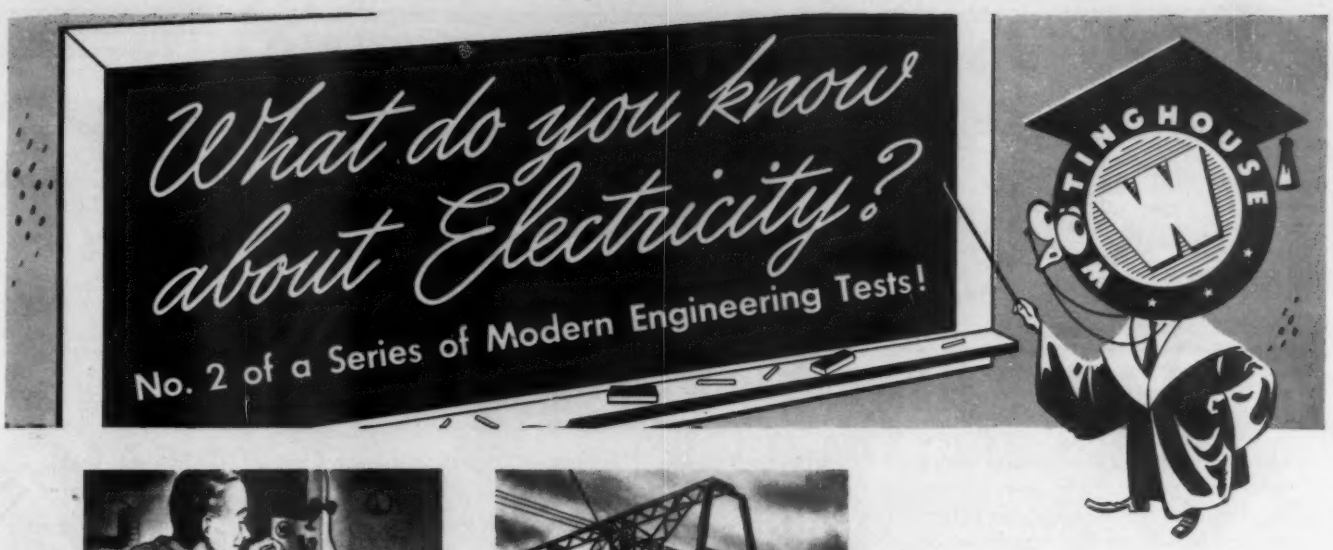
What of the war's repercussions in this country? Our defense program is making us more self-sufficient than ever. Will we maintain the war-stimulated industries with subsidies? What about excess plant capacity? What of the men trained for jobs in the defense industries? Who will own and operate the government-built plants? What about the national debt? What social transformations will occur? Our job is cut out for us; the questions can not go unanswered.

Immediate expansion is of course absolutely necessary, but a system — a master plan — must be set up for curtailing and transforming old, uneconomical capacity late. Mr. Batt emphasized the need for an industrial demobilization plan to be set up by a small group of the ablest men in the country for "conversion of the processes of economic waste to processes of economic usefulness."

One answer to Mr. Batt's desires will be found in the new program to be organized at the Institute by Professor Ralph E. Freeman, head of the Department of Economics and Social Sciences. This graduate program will stress the combination of engineering techniques with those of the social sciences. There will be close association with the work of the business and engineering administration department and with the field of industrial statistics. The course will fit graduate students for teaching, research, and industrial consulting careers.

Professor Freeman's course will undoubtedly fill one very vital need in the industrial demobilization plan; but the major move indicated by Mr. Batt is yet to be made.

R. I. Nesmith



THE OSCILLOGRAPH

The Westinghouse cathode-ray oscillograph makes written records of electrical events occurring in as short a time as:

1. One second
2. One cycle of a 60 cycle per second wave
3. One-thousandth of a second
4. One-millionth of a second.

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Lightning is a constant threat to transmission lines. Westinghouse has constructed lightning arresters that protect the highest voltage carried, which is:

1. 33,000 volts
2. 66,000 volts
3. 220,000 volts
4. 287,000 volts

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Great depth is being attained with electric rigs using Westinghouse equipment. To date, holes have been drilled as deep as:

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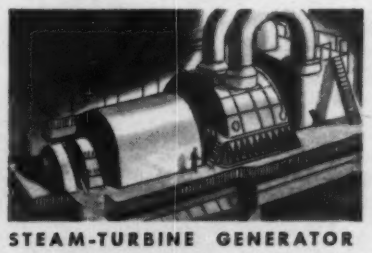
2. 4800 feet
3. Two and one-half miles
4. Six and one-third miles.



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1. A man in a launch
2. An electric eye
3. Radio signals from shore
4. A submerged cable.

DE-ION PRINCIPLE

As pioneered in 1928 by Dr. Joseph Slepian, Westinghouse Research Engineer, the De-ion principle is concerned with:

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3. The theory of magnetism
4. Harnessing the power of the atom.

Let's Try It Again!

Regardless of how you came out on the last series of questions, here's another chance for you to see how familiar you are with important developments in the field of electrical engineering.

Optional answers are provided for each of the six questions listed at the left. Your task is to check the correct answer in each instance. To eliminate any peeking, the answers are printed below, upside down.

If you get four out of six correct you'll be doing all right. Five out of six passes you with honors. If you should know all the answers you can give yourself a good pat on the back.

★ ANSWERS ★

The Oscillograph ..... Ans. 4.
Lightning Arresters ..... Ans. 4.
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WIE STARK IST DIE KRAFT?

(*Continued from page 28*)

operator is careful about processing the films and plotting the curves. The second source is made small by careful workmanship in the original construction. However, errors from the third source impose certain limitations which cannot be so readily overcome, such as those due to diffraction of transmitted light and the finiteness of the filament diameter.

It must not be imagined that this cinema integraph as described is the only type of integrating machine. Since Leibnitz invented the calculus and conceived the first mechanical integrator over two hundred years ago, men have sought after the ideal. In the Department of Electrical Engineering at the Massachusetts Institute of Technology, development of these mechanical "brains" has followed three lines.

First, is the process of solving complicated algebraic equations as they occur, for example, in modern power networks, by means of alternating current measurements made on a replica power system. This flexible aggregation of coils, resistances, and condensers, is known as the "network analyzer."

Second, is the optical system attack in integrals as first suggested by Wiener and now embodied in the cinema integraph.

Third, is the machine for solving differential equations. This is a purely mechanical combination of shafts, gears and pulleys. Termed as the "differential analyzer," it was developed to a high degree of accuracy by Dr. Vannevar Bush, now President of the Carnegie Institution, and formerly Vice-President of Technology.

At the present, a new electrical analyzer is being built in the Electrical Engineering Department, which will integrate successively eighteen times compared to only six times with the present mechanical machine of gears and pulleys! Among its projective applications is cosmic ray research.

Now, let us return to the cinema integraph and the example of the ship tossed about by the sea. In determining the righting moments about a longitudinal axis of a ship in still water, consider the hull divided into a large number of equally spaced cross sections. Each of these cross sections is transferred to a strip of film as transparent regions, the surrounding area being opaque. This is one variable function. The other variable introduced into the second aperture is a wedge-shaped strip of film serving to multiply the buoyant force on each longitudinal vertical element of the hull by its horizontal traverse distance from the center of gravity of the vessel. In the calibrations and operations, account is also taken of the water level, immersion of the center of gravity, and rolling effects. Hence, for each hull section represented in the film, the cinema integraph indicates the net righting moment for the given immersion and angle of heel.

By suitable modification of the foregoing procedure, rolling moments, buoyant forces, pitching moments, and finally the stresses on the ship itself can all be computed. Because of the great labor involved in almost inhuman calculations, this has never before even approached practicality.

In a recent investigation, calculated motions of a hypothetical destroyer were used to provide data for an animated silhouette (X-ray view) of the ship in a head sea.

Another illustrative problem, which can be dealt with by this mathematical leviathan, is the "replacement problem." Given the life expectancy of a group of objects and the number of them to be maintained in service, what is the rate at which they must be replaced? This problem is of great interest, since the objects need not be of an inanimate form but may also be human beings or certain of their possessions which are subjected to active use.

The equation of a problem of this nature takes the form

$$N(t) = N(O)S(t) + \int_{o}^{t} R(T)s(t-T)dT$$

where in the case of light bulbs $N(t)$ is the total number of lamps required in service at any given time (t), $S(t)$ the life expectancy of such lamps; all are known quantities. $N(o)$ is the number of lamps placed in service at time zero, and the unknown function is the replacement rate $R(t)$. For a problem like this, the time required to obtain the unknown function is usually about twelve hours. For a homo sapien of the genus mathematica, it would take perhaps a week to solve!

Thus, we have seen how the cinema integraph answers not only the question, "*Wie gross ist die Kraft?*", but also others equally baffling. It may be used for seeking periodicities in such recurrent phenomena as rainfall, temperature, and river flow, to serve as a basis for prediction. Analysts will find the machine useful in determining how a structure will react to earthquakes, explosion, shocks, or the density of alternating current in a conductor. Indeed, this calculator and others may usher in a new era of engineering in which empirical methods recede even further into the background as the exactness of mathematics takes over.

Acknowledgments

The main source of information for this article has been the article "Cinema Integraph" by H. L. Hazen, Sc.D. and G. S. Brown, Sc.D., as it appeared in the July and August 1940 issues of the *Franklin Institute.* Information of historical nature was obtained from a pamphlet by V. Bush, Eng.D., called "The Differential Analyzer," as well as the November 1939 and December 1940 issues of *Technology Review.*

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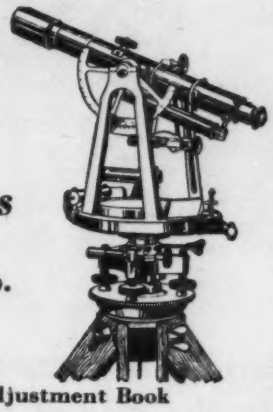

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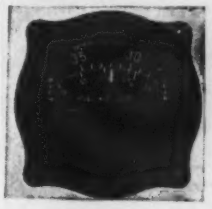

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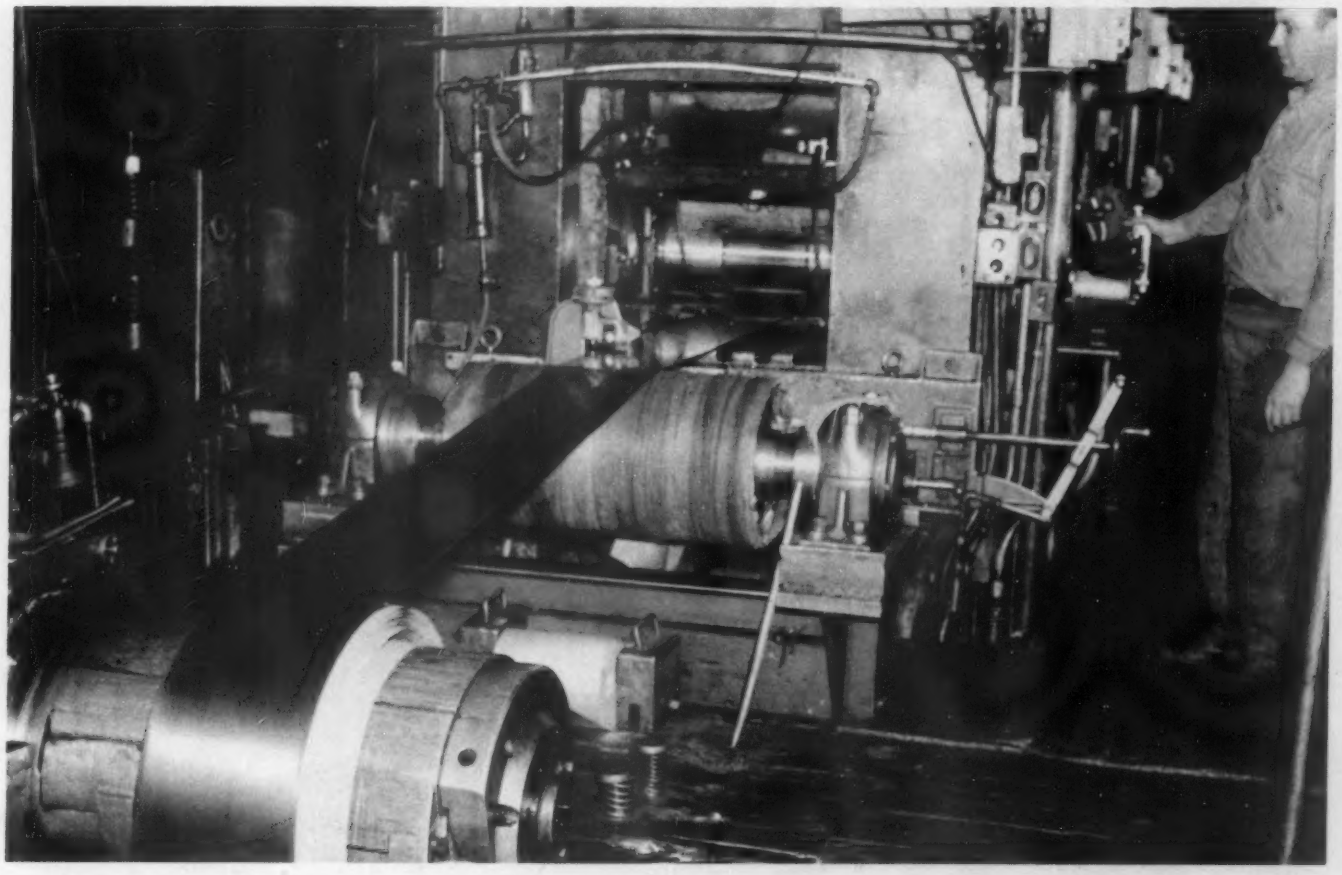

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STAINLESS STEEL

(*Continued from page 36*)

attack by sulfur-bearing gases at high temperature is necessary. Because of these properties, diversified applications have been found in annealing and many other types of furnaces, recuperators, heat exchangers, and ducts conveying corrosive gases at high temperature."[1]

Nickel and manganese give toughness and workability to stainless alloys. A small quantity of manganese is present in nearly all stainless steels, and some manufacturers even add one per cent nickel to straight chromium alloys of steel for the increase in hardenability that it effects. Molybdenum or copper add chemical resistance, while silicon protects against scaling. Selenium, zirconium or sulfur aid machinability.

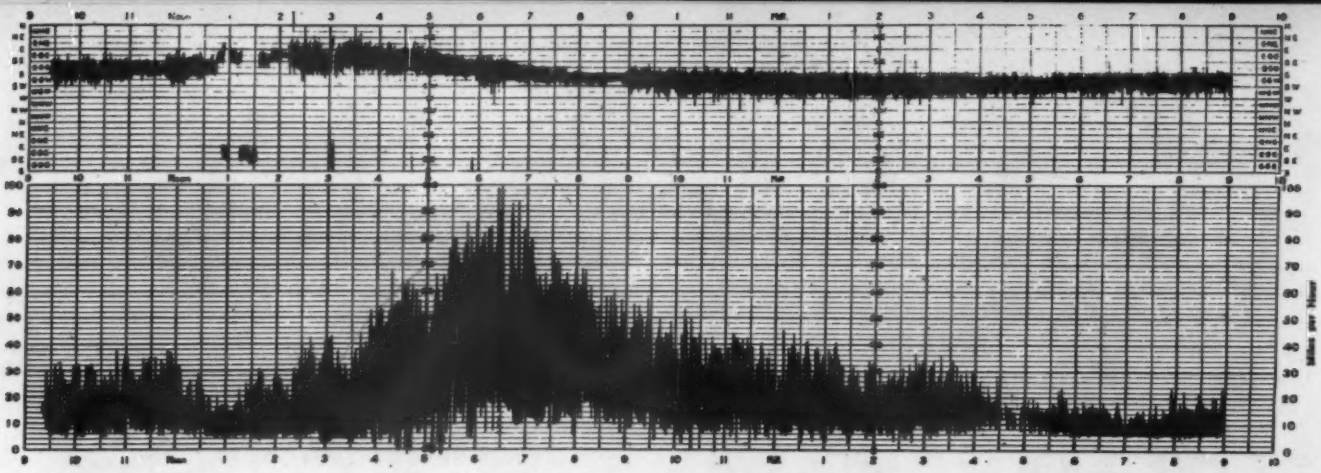
The somewhat higher cost of stainless steel is due to the long and painstaking process of manufacturing that it must undergo. All ingredients must be extremely carefully measured because of the great variability of stainless alloys. The steel goes through many rolling operations, each taking twice as long as for ordinary steel. More than half the original material is wasted during the rolling, cropping, trimming, and grinding processes.

[1] J. H. Critchett: "Twenty Years of Alloy Steel," *Chemical Industries Magazine*, March and April, 1940.

The principal property of stainless steel is its corrosion resistance. This resistance, however, is not complete; there are numerous substances that easily react with stainless alloys. Acetic acid vapor, lactic acid, and many other substances cannot be resisted by the chrome-alloyed steel. Some of its physical properties are also important: its machinability and its hardenability.

The first use of stainless steel was in the cutlery industry. The World War, however, taught man its true value. The Minister of Munitions of Great Britain used it on the exhausts of aero-engines. Today it is used throughout industry in tools, machinery, turbine blades, et cetera. Other uses are: surgical instruments, fine instruments such as those used in drawing, and golf club heads.

We have seen that stainless steel serves industry, humanity, and science; but we have only begun to see what great things can be done with it. Industry is using it in new ways, while science is improving it. The whole world of steel will appreciate its importance to everyday life. It will come into general use, and if it continues to progress as it has previously, we shall see a bright future for stainless steel.



Record of 1938 hurricane from the pressure tube anemometer and wind direction recorder. Note maximum velocity of 99 m.p.h. The highest wind velocity ever recorded by instruments, 231 m.p.h., came earlier in the year on Mt. Washington.

MAN VS. WEATHER

(*Continued from page 34*)

ing items. More and more research will be necessary before these problems can be solved. Now much has been "done" about the weather in an analytical sense. Meteorology has made life easier for the farmer, the aeroplane pilot, the seaman, the doctor, the fireman, and the layman as well. There are fewer accidents and fires, better crops, less disease. Everyone seems to have profited by this "eavesdropping on the elements." And as far as doing something about the weather in the practical sense of the word, successful experimental work has already been done in that direction.

One of the most interesting evidences of such progress is the recent experimentation in fog-dispersing. The media by means of which fog may be satisfactorily dispelled, may be divided into three major groups: chemical, physical and thermophysical, electrical and sonic.

The method of dispersion of fog by chemical drying agents such as sulfuric acid and calcium chloride is easily understood, even by the layman. By means of special nozzles, great volumes of solutions of those substances are spread over large areas. It has been found, in addition, that the calcium chloride method is more effective in dispelling fog than any other.

Physical and thermophysical removal of fog involves such devices as baffles, into which are drawn great masses of air in a manner similar to that employed in wind tunnels. Such a procedure removes a comparatively small amount of water vapor at a great expense. Another attempt, which has been made, is to remove water vapor from air by dropping solid particles from a height. This has proved to be quite inefficient due to the fact that the particles must be spherical in shape for the greatest effect. Thermophysical methods are demonstrated by such operations as passing fog-laden air through heated, fan-driven vents, or by spreading on the ground chemicals which react exothermically with water and carbon dioxide, such as calcium oxide. The former method is not practical because of the expense involved, and also because air often becomes resaturated as soon as it has cooled; the latter method has proved unsatisfactory because the suspension of calcium hydroxide solution in the air has a tendency to react with the aluminum of aeroplanes to produce soluble aluminates.

The last group — the electrical and sonic methods of fog dissipation — are by far the most interesting from a scientific point of view.

Electrically, fog is dispelled by the distribution of charged particles in the air, which agitate the water droplets so that they unite with neighboring ones and fall as rain. The main trouble with this charged-particle technique is that the charge tends to leak off as brush discharge unless these particles are perfectly spherical. Since ordinary sand is the most common vehicle for the charge, the rounding of millions of grains of finely divided material to clear only a small area from fog would be an absurd, let alone impracticable procedure, and consequently the plan has been temporarily discarded.

Sonic, or more accurately, supersonic dispersion of fog is a comparatively new development, and is entitled to a little serious consideration. When amplified sounds of very high frequency (chiefly between twenty and fifty thousand vibrations per second, much above the hearing capacity of the normal human ear) are focused by reflectors on fog-filled air, drops of rain soon begin to fall, and the area within range of the reflectors becomes clear in a reasonably short time.

There are several explanations given to this phenomenon. The two most universally accepted concern resonant motion and Bernoulli's gas energy law. As for the first, when high frequency waves pass through the air, certain water particles will be of such size as to vibrate in phase with this air motion, while larger and smaller particles will not. This gives rise to an oscillation of some globules in one direction, and others in another. The result is numerous collisions in which particles unite by surface tension and become large enough to fall as rain.

The second explanation depends on Bernoulli's theorem, which states that a gas with a fixed amount of total energy exerts less pressure at high speeds than at low ones. This principle can be applied to our present situation without difficulty: High-frequency sound produces vibrations of the air which are sufficiently small to find their way *between* fog particles (which, incidentally, are no more than a micron or two apart); due to the speed of these minute air currents, the particles will be drawn together.

Though this method of fog precipitation is still in its embryonic stages, and although chemical dispersing mediums are at present more successful from an economical point of view, it is believed that development of larger and more efficient apparatus to handle several acres of ground will be of inestimable value to air transportation.

In conclusion — to the skeptic who refuses to believe man's interest in the weather will have any significance in the future — we say, "See what has been accomplished in the past few years, and judge for yourself."

Harold Orne

ABOVE. From right to left:
Recording rain gauge. Recorder for the pressure tube anemometer and wind vane on which a continuous record of wind velocity and direction is obtained. Recording thermometer or Thermograph, giving a continuous record of the air temperature. Barograph, giving a record of the atmospheric pressure.

BELOW. This is the curve of the air pressure vs. time during the 1938 hurricane.

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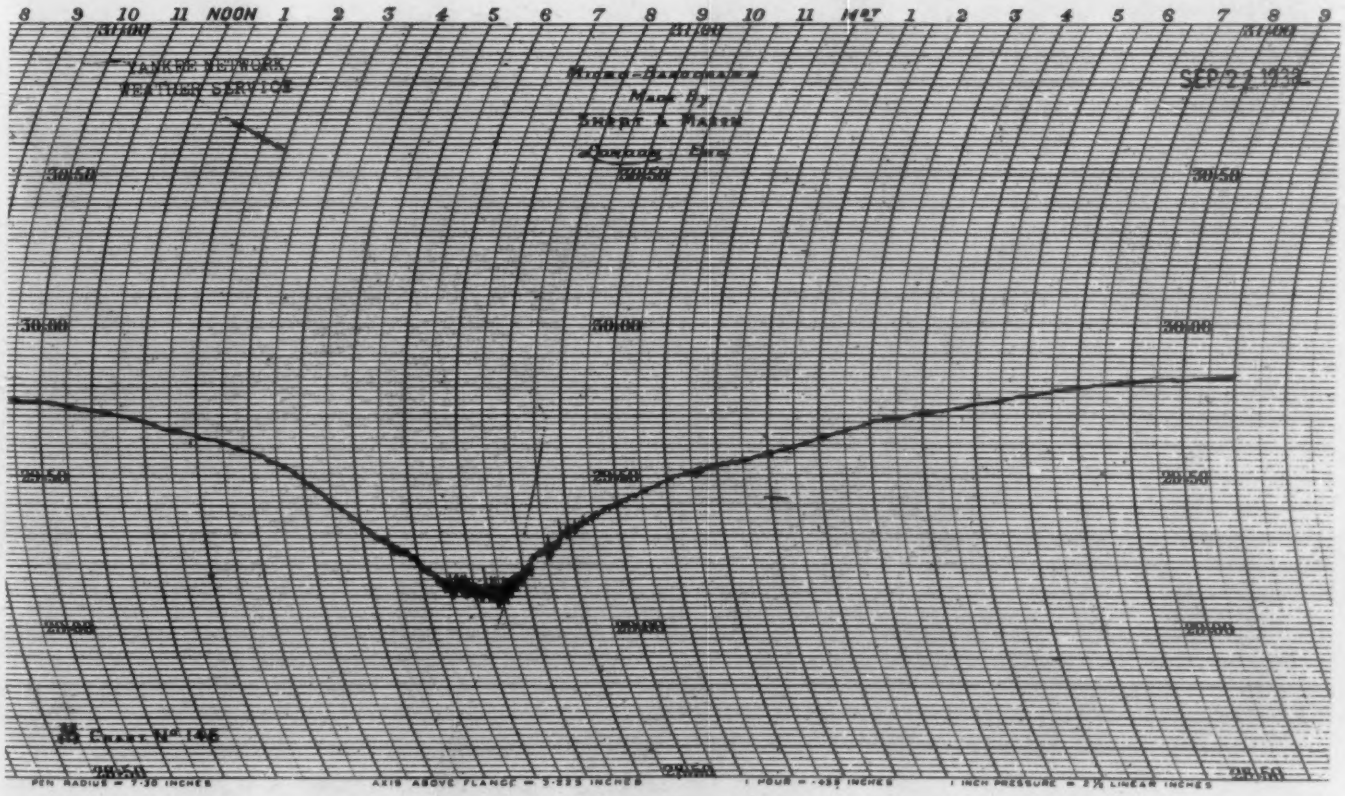
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SEP 21 1938
30.50
30.00
29.50
29.00
28.50
PEN RADIUS = 7.30 INCHES
AXIS ABOVE FLANGE = 3.225 INCHES
1 HOUR = .025 INCHES
1 INCH PRESSURE = 2.5 LINEAR INCHES

THE FIGHT AGAINST FRICTION

(*Continued from page 30*)

The lubricant used in the Superfinish process is utilized only as a lubricant and not as a coolant, as in other processes. The low speed of the Superfinish operation keeps the temperature low enough to permit the liquid to wash away the fragmented metal and bits of loose abrasive, and thus prevents them from continuing the cutting action after the work has attained the specified size. As the work approaches this required size, the lubricant controls the finishing operation by balancing the pressures between the abrasive and the work so that no matter how long the operation is continued, no material beyond the specified dimension will be removed.

As a consequence of all these factors concerning tools, multimotion, abrasive pressure, speed, and lubricant, the process of Superfinish is an exceedingly speedy one. No Superfinish operation for any part takes more than fifty seconds, and this fact alone determines the economic and industrial feasibility of the scheme.

The metallurgical complexity of a machined surface is readily recognized. An explanation, however, of that portion of metallurgy which directly affects the minute layer of a finished surface, might be wise. Before beginning this, it must be stressed that in a metal, the surface alone is what determines the load-carrying capacity. It may be thought of as being held in place by the body of the specimen.

In the discussion of metallurgical nomenclature, it is necessary to recognize the existence of a crystalline structure. These minute crystals have been referred to as the metallurgists' bricks, from which they may build the metal as it is known. As cement holds bricks together, so a metal cement acts as a bond between the metal crystals. This cement has been determined to be essentially amorphous, or non-crystalline in structure. This amorphous cement is actually harder than the crystalline metal itself at room temperature, but at the temperatures and pressures generated in a machining operation, it softens and flows into the tiny crevices in the crystalline material, and for this reason it has been likened to a metallic paint.

It has been shown that a surface thus coated with this "smear metal" detrimentally affects the load carry-

(*Continued on page 48*)

A special machine for surfacing crankshaft bearings — *Chrysler*

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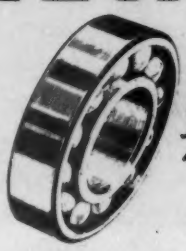
***ENGINEERING STUDENTS:** For interesting brochure, "Accuracy Pays Extra Dividends," write to New Departure, Division General Motors Sales Corporation, Bristol, Conn.*

NEW DEPARTURE



BALL BEARINGS

Nothing Rolls Like a Ball

THE FIGHT AGAINST FRICTION

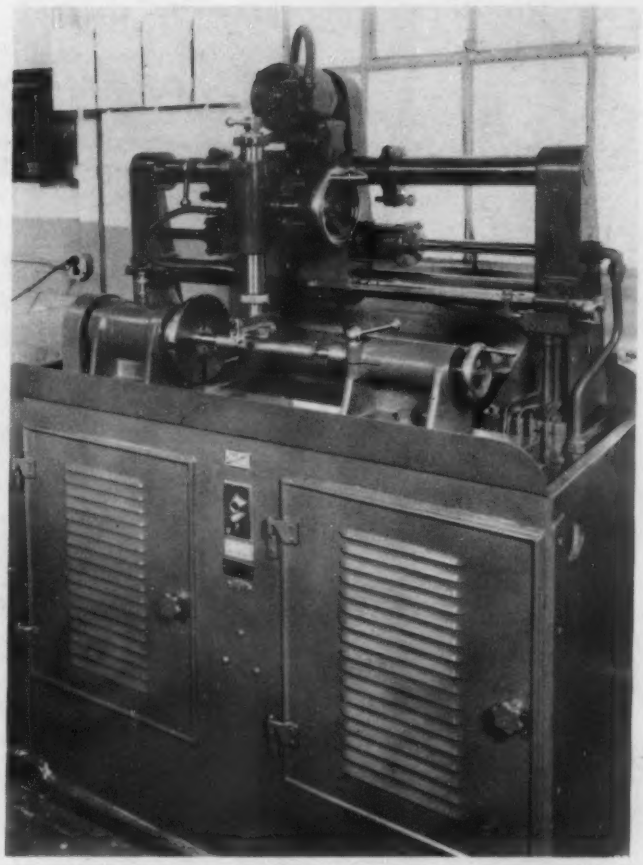
(*Continued from page 46*)

ing ability, and since the cement is harder at lower temperatures than the crystalline base, it flashes off and acts as an abrasive, and as such, causes rapid wear. In view of these facts, it is obviously an advantage to remove as much of this "smear" layer as possible, as the maximum operation level for any part is dependent on the layers of which the bearing surfaces are composed.

With reference to the previous paragraph concerning the Superfinish process, it was noted that one of the principal steps in the attainment of this fine finish was a slow abrasive speed and a consequently low temperature. These conditions are in direct antithesis to those mentioned above for the existence of smear metal, and as a consequence, a Superfinished surface very nearly represents an unworked surface with respect to crystal deformation and smear metal existence.

The manufacturing advantages of the Superfinish process include a low machining time, simple preliminary operations, and a high degree of dimensional accuracy. Among the engineering advantages, the Superfinish process boasts wear-proof bearings, the elimination of oil film rupture, and a maintenance of initial clearances. Because of its ability to expose more crystalline material on a surface through the effective reduction of smear formation, the process has been termed ultimate.

The desirability of such a development cannot be questioned. Technology has taken another step forward toward solving the problem of friction, nature's oldest riddle.



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1 **. . . so that the telephone subscriber can say:**

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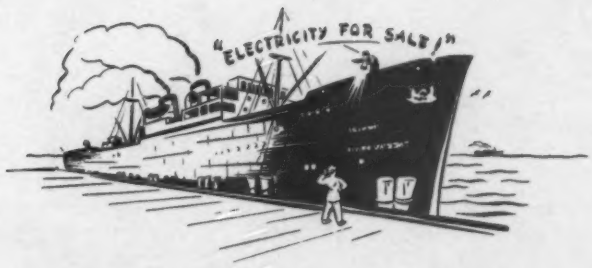
G-E Campus News



FLOATING POWER

BACK in '29, when the water supply in Tacoma, Washington, was so low that the hydro-electric stations could not generate enough electricity for the city's requirements, the U.S.S. *Lexington*—a turbine-electric drive airplane carrier—supplied the power necessary to tide the city through the emergency.

A year later on the opposite side of the country, the *Tacoma*, a ship built during the last war, was made into a floating power plant by installing two 10,000-kw turbine-generators in its hull. It is at present in service on the Piscataqua River near Portsmouth, N. H.

General Electric is now studying the possibilities of a 50,000-kw floating power plant, which could be towed through America's coastal and inland waterways and hooked up to regular distribution lines to generate electricity in emergencies. Such a generating station could be housed in a hull similar to that of a lake freighter.

GIANT ATOM SMASHER

SO powerful that its atom-smashing beam of ions would melt an ordinary brick as fast as a blowtorch would melt a pound of butter will be the U. of California's new 100,000,000-volt cyclotron. The 4900-ton giant—16 times more powerful than the present outfit—will generate atomic energies greater than any now in existence except in distant stars or elsewhere in cosmic space.

Atomic particles will be fed into a circular chamber where they will receive successive "kicks," whirling them around in continually widening circles until they reach a window or port on the side of the chamber. The element to be bombarded will be placed over this window where it will receive the full force of the ion beam.

For this machine General Electric is building electric equipment, which will occupy the space of a two-story house. The chief function of this equipment will be to make ordinary electric current capable of operating the giant atom smasher.

DETECTIVE STORY

ALBANY HOSPITAL was in an uproar. The technicians in charge of the hospital's radium supply had lost a radium "needle"—only 3.3 milligrams to be sure, but enough to burn a person seriously if the needle were caught for long in his shoe or clothing.

An appeal for help was sent to the General Electric Research Laboratory in Schenectady for a "Geiger Counter"—an electric "ear" which detects and amplifies the otherwise inaudible "explosion" of the radium as it breaks down.

When Dr. C. W. Hewlett (N. C. State, '06) of the G-E Research Laboratory entered the suspected operating room, the counter immediately began to "cluck" its warning of radioactivity nearby. After a false start, the counter took to the trail like the Hawkshaw it is, and eventually, as Dr. Hewlett lowered it to the floor in front of a radiator, the clucks became barks. And there, snuggled against the wall under the radiator, was the missing radium.

GENERAL ELECTRIC

263-15

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